1.5 MOULDING PROCESSES

Classification of Casting Processes:

Casting processes can be classified into following FOUR categories:

1. **Conventional Moulding Processes**
a. Green Sand Moulding
b. Dry Sand Moulding
c. Flask less Moulding
2. **Chemical Sand Moulding Processes**
a. Shell Moulding
b. Sodium Silicate Moulding
c. No-Bake Moulding
3. **Permanent Mould Processes**
a. Gravity Die casting
b. Low and High Pressure Die Casting
4. **Special Casting Processes**
a. Lost Wax or Investment Casting
b. Ceramics Shell Moulding
c. Evaporative Pattern Casting
d. Vacuum Sealed Moulding
e. Centrifugal Casting

Green Sand Moulding

Green sand is the most diversified moulding method used in metal casting operations. The process utilizes a mould made of compressed or compacted moist sand. The term "green" denotes the presence of moisture in the moulding sand. The mould material consists of silica sand mixed with a suitable bonding agent (usually clay) and moisture.

Advantages
Most metals can be cast by this method.
Pattern costs and material costs are relatively low.
No Limitation with respect to size of casting and type of metal or alloy used.

Disadvantages
Surface finish of the castings obtained by this process is not good and machining is often required to achieve the finished product.

Sand Mould Making Procedure

Typical sand moulds have the following parts:
• The mould is made of two parts, the top half is called the cope, and bottom part is the drag.
• The liquid flows into the gap between the two parts, called the mould cavity. The geometry of the cavity is created by the use of a wooden shape, called the pattern. The shape of the patterns is (almost) identical to the shape of the part we need to make.
• A funnel shaped cavity; the top of the funnel is the pouring cup; the pipe-shaped neck of the funnel is the sprue – the liquid metal is poured into the pouring cup, and flows down the sprue.
• The runners are the horizontal hollow channels that connect the bottom of the sprue to the mould cavity. The region where any runner joins with the cavity is called the gate.
• Some extra cavities are made connecting to the top surface of the mould. Excess metal poured into the mould flows into these cavities, called risers. They act as reservoirs; as the metal solidifies inside the cavity, it shrinks, and the extra metal from the risers flows back down to avoid holes in the cast part.
• Vents are narrow holes connecting the cavity to the atmosphere to allow gasses and the air in the cavity to escape.

• Cores: Many cast parts have interior holes (hollow parts), or other cavities in their shape that are not directly accessible from either piece of the mould. Such interior surfaces are generated by inserts called cores. Cores are made by baking sand with some binder so that they can retain their shape when handled. The mould is assembled by placing the core into the cavity of the drag, and then placing the cope on top, and locking the mould. After the casting is done, the sand is shaken off, and the core is pulled away and usually broken off.

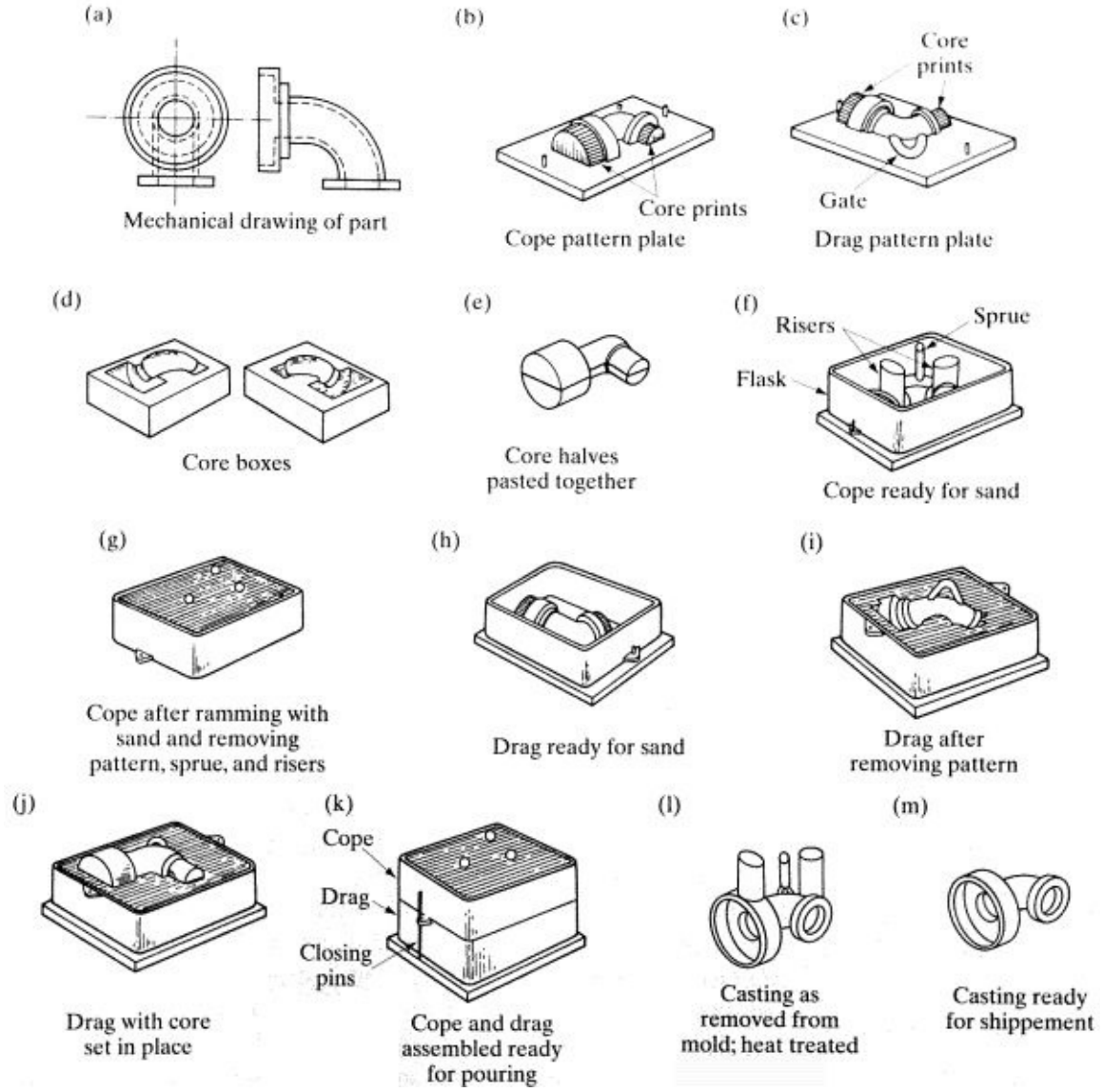


Figure 1.5.1: Schematic showing steps of the sand casting process [source: Kalpakjian and Schmid]

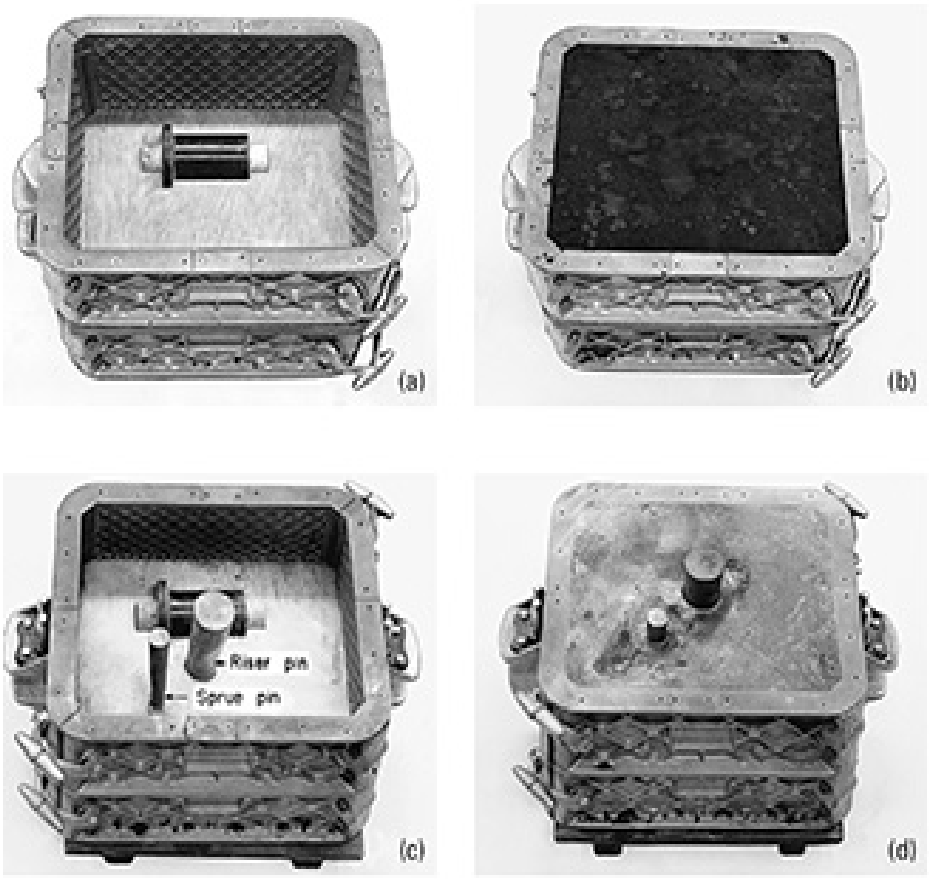


Figure 1.5.2: Sand moulding process

Dry Sand Moulding

When it is desired that the gas forming materials are lowered in the moulds, air dried moulds are sometimes preferred to green sand moulds. Two types of drying of moulds are often required.

1. Skin drying and
2. Complete mould drying.

In skin drying a firm mould face is produced. Shakeout of the mould is almost as good as that obtained with green sand moulding. The most common method of drying the refractory mould coating uses hot air, gas or oil flame. Skin drying of the mould can be accomplished with the aid of torches, directed at the mould surface.

Shell Moulding

It is a process in which the sand mixed with a thermosetting resin is allowed to come into contact with a heated metallic pattern plate, so that a thin and strong shell of mould is formed around the pattern. Then the shell is removed from the pattern and the cope and drag are joined together and kept in a flask with necessary back up material and molten metal is poured into the mould. Dry and fine sand (90 to 140 GFN) which is completely free of the clay is used for preparing the shell moulding sand. The grain size to be chosen depends on the surface finish desired on the casting. Too fine a grain size requires large amount of resin which makes the mould expensive.

The resins most widely used, are the phenol formaldehyde resins, which are thermosetting in nature. Combined with sand, they give very high strength and resistance to heat. The resin initially has excess phenol and acts like a thermoplastic material and coated the sand particles. After that in the presence

of a catalyst such as hexa-methylenetetramine (hexa) it develops thermosetting characteristics. The curing temperature for these would be around 150^0C and the time required would be 50 to 60 seconds. Additives like coal dust, pulverized slag, manganese dioxide, calcium carbonate, ammonium borofluoride and magnesium silicofluoride etc. are added to the sand mixture to improve the surface finish and avoid thermal cracking during pouring. The lubricants like calcium stearate and zinc stearate are added to improve the flowability of the sand and permit easy release of the shell from the pattern.

Moulding Procedure

1. The sand, hexa and additives which are all dry, are mixed inside sand Mueller for a period of 1 minute. Then liquid resin is added and the mixing is continued for another 3 minutes. To this cold or warm air is introduced into the Mueller and the mixing is continued till all the liquid is removed from the mixture and coating of the grain is achieved to the desired degree. For cold mixing, powdered bakelite in acetone is used as binder and ethyl aldehyde as additive. Only metal (cast iron, steel or aluminium) patterns with associated gating & risering provisions are used because the sand resin mixture is to be cured at about 150^0 C.
2. The metallic pattern plate is uniformly heated to a temperature of 200 to 350^0 C(depends on pattern materials) such that temperature variation across the whole pattern is within 25 to 40^0 C depending on the size of the pattern.
3. A silicone release agent is sprayed on the pattern and the metal plate.
4. The heated pattern is securely fixed to a dump box as shown in Fig.1.5.3, wherein the coated sand in an amount larger than required to form the shell of necessary thickness is already filled in.
5. The dump box is rotated so that the coated sands fall on the heated pattern. The heat from the pattern melts the resin adjacent to it thus causing the sand mixture to adhere to the pattern.
6. When a desired thickness of the shell is achieved, the dump box is rotated backwards by 180^0 so that the excess sands falls back into the box, leaving the formed shell intact with the pattern. The average shell thickness achieved depends on the temperature of the pattern and the time the coated sands remain in contact with the heated pattern. The shell thickness (2 to 8 mm) required depends on the pouring metal temperature and the casting complexity.
7. The shell along with the pattern plate is kept in an electric or gas fired oven for curing the shell. The curing should be done as per requirement because over curing may cause the mould to break down as the resin would burn out. The under curing may result in blow holes in the casting or the shell may break during handling due to lack of strength.
8. The pattern plate is detached from the shell and two halves of the shells are joined together either by mechanical clamping or adhesive bonding. The adhesive may be applied at the parting plane before mechanical clamping and then allowed for 20 to 40 seconds for achieving the necessary bonding.
9. Since the shells are thin, they may require some outside support so that they can withstand the pressure of the molten metal. A cast iron shot is generally used as it occupies any contour without unduly applying any pressure on the shell. With such a backup material, it is possible to reduce the shell thickness to an economical level.

Advantages

- Shell mould castings are generally more dimensionally accurate than sand castings. Tolerance is ± 0.25 mm for steel castings and ± 0.35 mm for grey cast iron and in case of close tolerance shell mould it is ± 0.03 to 0.13 mm.
- Using finer size sand grains a smoother surface finish (roughness of the order of 3 to 6 microns) can be obtained.
- Lower draft angles (50 to 75 % less) compared to conventional casting saves the material costs and the subsequent machining costs.
- Since the sand has high strength, the mould could be designed in such a manner the internal cavities can be formed directly with shell mould itself without the need of special cores.
- Very thin sections (up to 0.25 mm) of the type of air cooled cylinder heads can be readily made because of higher strength of the sand used for moulding.
- Permeability of the shell is high and therefore no gas inclusions occur.
- Very small amount of sands required.

- Mechanization is readily possible because of the simple processing involved in shell moulding.

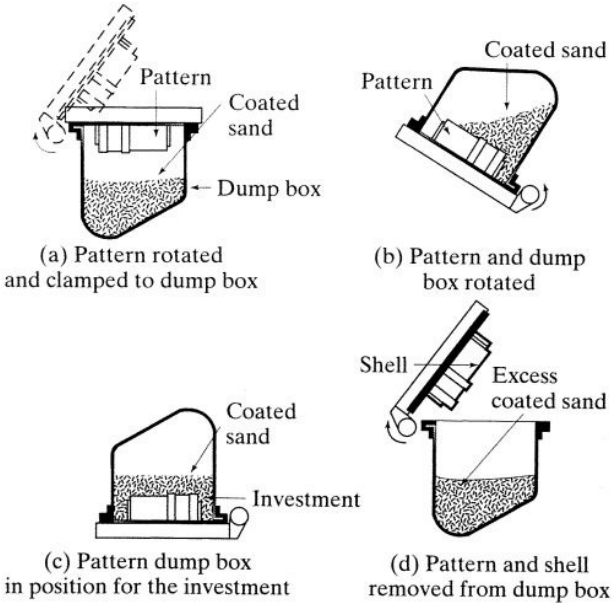


Figure 1.5.3: Shell moulding process (1)

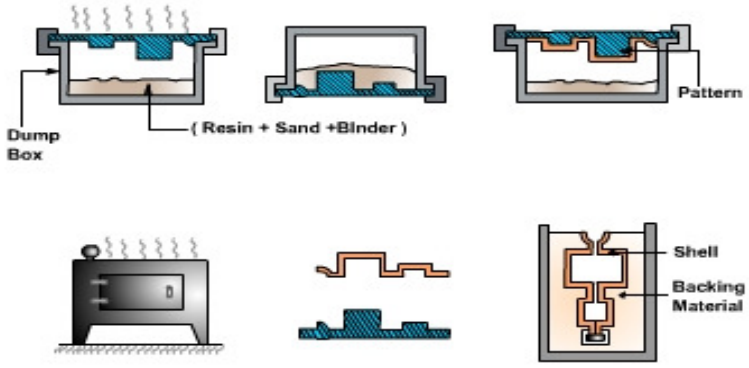


Figure 1.5.4: Shell moulding process (2)

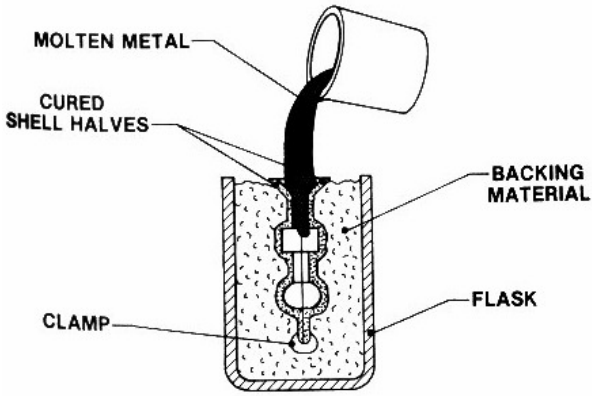


Figure 1.5.5: Shell moulding process (3)

Disadvantages

- The patterns are very expensive and therefore are economical only if used in large scale production. It becomes economical over sand moulding above 15,000 pieces.
- The size of casting obtained by shell moulding is limited. Casting weighing up to 200 Kg can be made, though in smaller quantity castings up to a weight of 450Kg were possible.
- Highly complicated shapes can not be obtained.
- More sophisticated equipment is needed for handling the shell moulding such as those required for heated metal patterns.

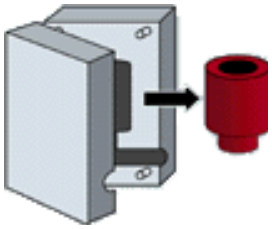
Applications

Casting of following items

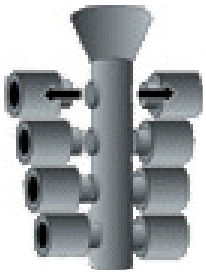
- Cylinders and cylinder heads for air cooled IC engines, automobile transmission parts, cast tooth bevel gears, brake beam, hubs, track rollers for crawler tractors, steel eyes, gear blanks, chain seat brackets, refrigerator valve plate, small crank shafts

Precision Investment Casting

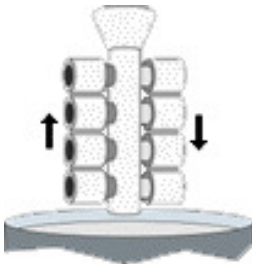
This is the process where the mould is prepared around an expendable pattern. The first step in this process is the preparation of the pattern for every casting made. To do this, molten wax which is used a s the pattern material is injected under pressure of about 2.5 MPa into a metallic die which has the cavity of the casting to be made. The wax when allowed to solidify would produce the pattern. To this wax pattern, gates, runners and any other details required are appended by applying heat.



(a) Wax patterns are produced by injection molding.



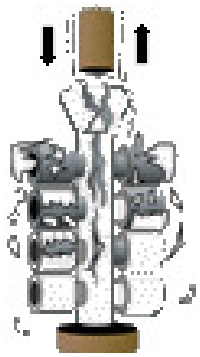
(b) Multiple patterns are assembled to a central wax sprue.



(c) A shell is built by immersing the assembly in a liquid ceramic slurry and then into a bed of extremely fine sand. Several layers may be required.

(d) The ceramic is dried; the wax is melted out; ceramic is fired to burn all wax.

(e) The shell is filled with molten metal by gravity pouring. On solidification, the parts, gates, sprue and pouring cup become one solid casting. Hollow casting can be made by pouring out excess metal before it solidifies.



(f) After metal solidifies, the ceramic shell is broken off by vibration or water blasting.

(g) The parts are cut away from the sprue using a high speed friction saw. Minor finishing gives final part.

Figure 1.5.6: Investment casting process (1)

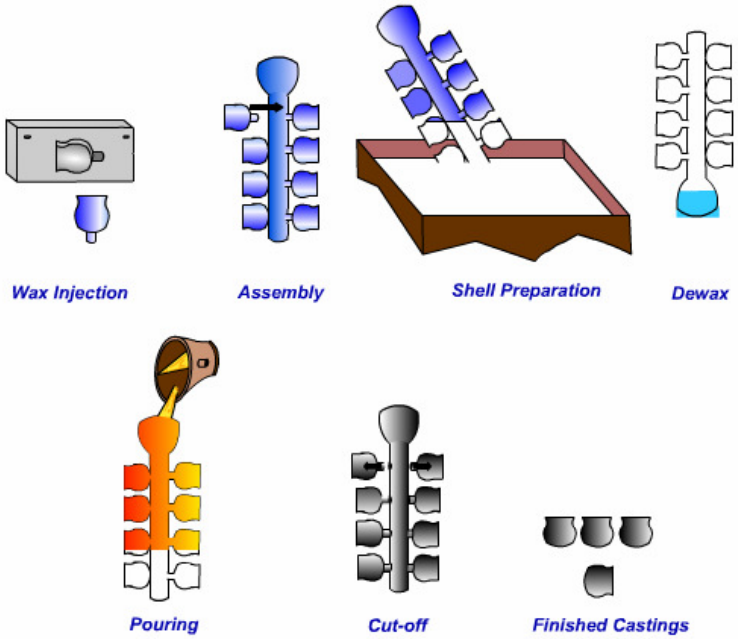


Figure 1.5.7: Investment casting process (2)

To make the mould, the prepared pattern is dipped into slurry made by suspending fine ceramic materials in a liquid such as ethyl silicate or sodium silicate. The excess liquid is allowed to drain off from the pattern. Dry refractory grains such as fused silica or zircon are stuccoed on this liquid ceramic coating. Thus a small shell is formed around wax pattern. The shell is cured and then the process of dipping and succoing is continued with ceramic slurries of gradually increasing grain sizes. Finally when a shell thickness of 6 to 15 mm is reached, the mould is ready for further processing. The shell thickness required depends on the casting shape and mass, type of ceramic and the binder used.

The next step in the process is to remove the pattern from the mould, which is done by heating the mould to melt the pattern. The melted wax is completely drained through the sprue by inverting the mould. Any wax remnants in the mould are dissolved with the help of the hot vapour of a solvent, such as trichloro-ethylene. The moulds are then pre-heated to a temperature of 100 to 1000^0 C, depending on the size, complexity and the metal of the casting. This is done to reduce any traces of wax left off and permit proper filling of all mould sections which are too thin to be filled in a cold mould. The molten metal is poured into the mould under gravity, under slight pressure, by evacuating the mould first. The method chosen depends on the type of casting.

Advantages

- Complex shapes which are difficult to produce by any other method are possible since the pattern is withdrawn by melting it.
- Very fine details and thin sections can be produced by this process, because the mould is heated before pouring.
- Very close tolerances and better surface finish can be produced. This is made possible because of the fine grain of sand used next to the mould cavity.
- Castings produced by this process are ready for use with little or no machining required. This is particularly useful for those hard to machine materials such as nimonic alloys.
- With proper care it is possible to control grain size, grain orientation and directional solidification in this process, so that controlled mechanical properties can be obtained.
- Since there is no parting line, dimensions across it would not vary.

Limitations

- The process is normally limited by size and mass of the casting. The upper limit on the mass of a casting may be of the order of 5 Kg.
- This is a more expensive process because of larger labour involved in the preparation of the pattern and the mould.

Application

The products made by this process are vanes and blades for gas turbines, shuttle eyes for weaving, pawls and claws of movie cameras, wave guides for radars, bolts and triggers for fire arms, stainless steel valve bodies and impellers for turbo chargers.

Permanent or Metal Moulding

For large-scale production, making a mould, for every casting to be produced, may be difficult and expensive. Therefore, a permanent mould, called the die may be made from which a large number of castings, anywhere between 100 to 2,50,000 can be produced, depending on the alloy used and the complexity of the casting. This process is called permanent mold casting or gravity die casting, since the metal enters the mould under gravity.

The mould material is selected on the consideration of the pouring temperature, size of the casting and frequency of the casting cycle. They determine total heat to be borne by the die. Fine grained cast iron, alloy cast iron, C20 steel and alloy steels (H11 and H14) are commonly used materials for this type of mould. Graphite moulds may be used for small volume production from aluminium and magnesium. For making any hollow portions, cores are also used in permanent mould casting. It can be made out of metal, or sand. When sand cores are used, the process is called semi-permanent moulding. The metallic core cannot be complex with under-cuts and like. Also it is to be withdrawn immediately after solidification, otherwise, its extraction becomes difficult because of shrinkage. For complicated shapes, collapsible cores (multiple piece cores) are sometimes used in permanent moulds. Their use is not extensive because of the fact that it is difficult to securely position the core as a single piece as also due to the dimensional variations that are likely to occur. Therefore the designer has to provide coarse tolerance on these dimensions.

The mould cavity should be simple without any undesirable drafts or undercuts which interfere with the ejection of he solidified castings. In designing the mould care should be taken to ensure progressive solidification towards the riser. If the casting has heavy sections then mould sections around that area may be made heavier to extract more heat. Chills supported by heavy air blast may also be used to remove excess heat. The cooling channels may be provided at necessary area to get proper temperature distribution. The likely problems with cooling water circulation are the formation of scales inside the cooling channels and their subsequent blocking after some use. To get proper gating arrangements, it may be desirable first to experiment with various gating systems in sand casting and then finally arrive at the correct gating system for the metallic mould.

The moulds are coated with refractory materials to a thickness of 0.8 mm. The coatings are used to increase the mould life

- By preventing the soldering of metal to the mould,
- By minimizing the thermal shock to the mould materials, and
- By controlling the rate and direction of the casting solidification.

The coatings are mixtures of sodium silicate, kaolin clay, soap stone and talc. The coatings are both insulating type and lubricating type. The main requirement of a coating is that it should be inert to the casting alloy. It may be applied by spraying or brushing. It must be thick enough to fill up any surface imperfections and must be thicker at surfaces which need to be cooled slowly like sprue, runner, riser and thin sections. Under regular casting cycle, the temperature at which the mould is used depends on the pouring temperature, casting cycle frequency, casting weight, casting shape, casting wall thickness, wall thickness of the mould and thickness of the mould coating. If the casting is done with the cold die, the first few castings are likely to have mis-runs till the die reaches its operating temperature. To avoid this, the mould should be preheated to its operating temperature in an oven.

The materials which are normally cast in permanent moulds are aluminium alloys, magnesium alloys, copper alloys, zinc alloys and grey cast irons. The sizes of the castings are limited to 15 Kg for most of the materials while it may go up to 350 Kg only for aluminium. Permanent mould casting is suitable for high volume production of small simple shaped castings with uniform wall thickness and no intricate details.

Advantages

- Because of the metallic moulds used, this process produces a fine grained casting with superior mechanical properties.
- They produce very good surface finish of the order of 4 microns and better appearance.
- Close dimensional tolerances can be obtained.
- It is economical for large volume production as the labour involved in the mould preparation is reduced.
- Small cored holes may be produced compared to sand casting.
- Inserts can be readily cast in place.

Limitations

- The maximum size of casting that can be produced is limited because of the equipment.
- Complicated shapes cannot be produced.
- The cost of die is very high and can only be justified for large scale production.
- Not all materials are suited for permanent mould casting essentially because of the mould materials.

Applications

Some of the components that are produced in permanent mould castings are automobile pistons, stators, gear blanks, connecting rods, aircraft fittings, cylinder blocks, etc.

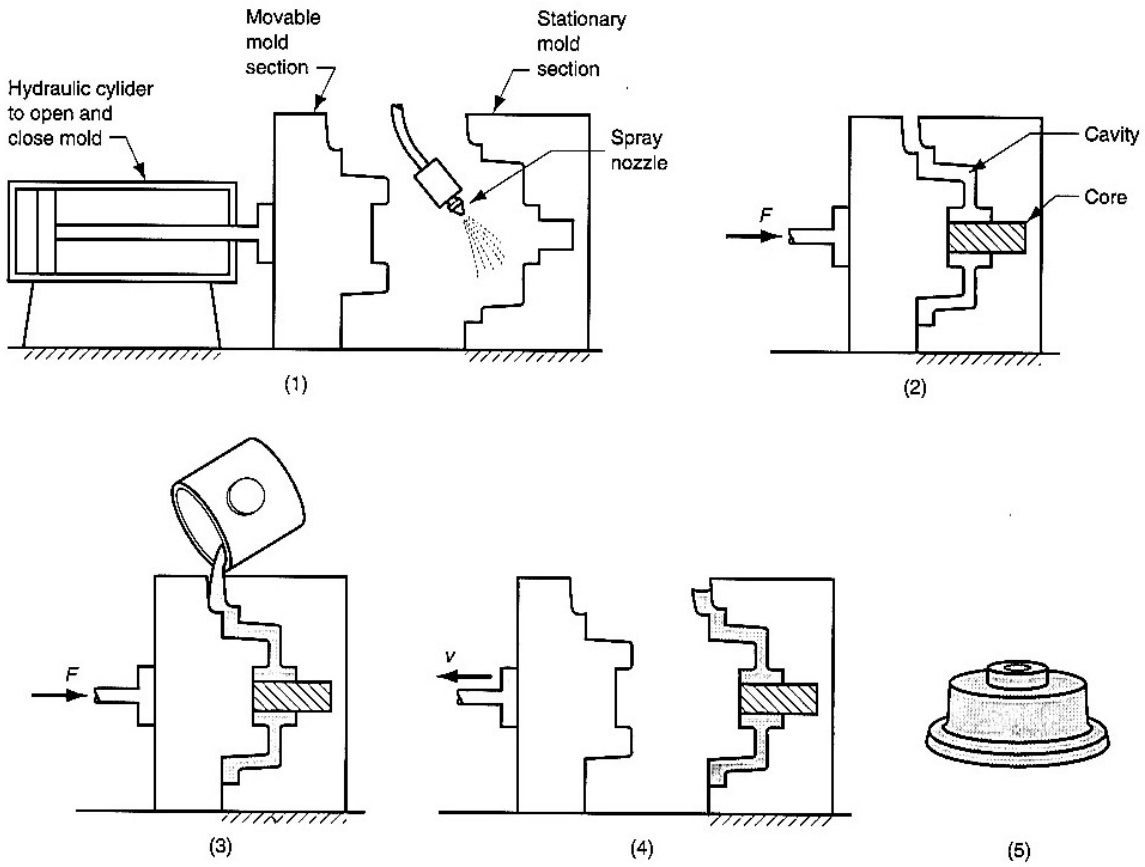


Figure 1.5.8: Permanent mould casting

Reference

1. Manufacturing Technology by P.N.Rao , TMH